

WHAT IS CLAIMED IS:

1. A powder inhaler comprising:

powder housing means for holding a supply of powdered material to be dispensed, said powder housing means including an inhalation conduit extending therethrough in a first direction, in displaced relation to said supply of powdered material;

metering plate means for holding a metered amount of said powdered material, said metering plate means including metered dose hole means for holding said metered amount of said powdered material, said metering plate means being positionable below said supply of powdered material, and said metering plate means and said powder housing means being relatively bi-directionally rotatable with respect to each other about a common central axis so that said metered dose hole means can be placed in fluid communication selectively with said supply of powdered material or said inhalation conduit;

spring means for biasing said metering plate means and said powder housing means toward each other to maintain contact therebetween;

rotation limiting means for restricting relative rotation between said powder housing means and said metering plate means to a predetermined angle;

counter means for providing a visual count of the number of doses of said powdered material that have been dispensed or remain to be dispensed in response to said relative rotation of said powder housing means and said metering plate means, said counter means including:

counter ring means for providing said visual count, said counter ring means being rotatable about said common central axis and having counting indicia thereon for displaying said visual count, and

actuating means for incrementally rotating said counter ring means in response to said relative

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rotation between said metering plate means and said powder housing means; and

display means through which one of said counting indicia from said counter ring means is displayed to indicate a count corresponding to a number of doses of powdered material that have been dispensed or remain to be dispensed.

b 2. The powder inhaler according to claim 1, further including an upper support plate positioned below and in contact with said metering plate means, said upper support plate having an opening larger than said metered dose hole means and in alignment with said metered dose hole means when said metered dose hole means is in alignment with said inhalation conduit, and said retainer means ^{including} includes a material secured to an underside of said upper support plate and formed by a material selected from the group consisting of a gas-permeable filter, a mesh screen, a porous material mesh and a perforated plate element.

3. The powder inhaler according to claim 1, wherein said powder inhaler includes a base having an axially extending retaining post thereon coaxial with said common axis, and said counter ring means is rotatably mounted on said base in surrounding relation to said retaining post.

4. The powder inhaler according to claim 3, wherein said counter ring means includes a continuous counter ring having counting indicia thereon, and an intermittent counter ring coaxially mounted with said continuous counter ring and having counting indicia thereon.

5. The powder inhaler according to claim 4, wherein said continuous counter ring has gear teeth

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therearound, said intermittent counter ring has gear teeth therearound, and said actuating means includes pawl means engaging with said gear teeth of said continuous counter ring and said intermittent counter ring for rotating said continuous counter ring one increment each time that a dose of the powdered material is dispensed to display another one of said counting indicia of said continuous counter ring through said display means, and for rotating said intermittent counter ring one increment every predetermined number of rotational increments of said continuous counter ring to display another one of said counting indicia of said intermittent counter ring through said display means.

6. The powder inhaler according to claim 5, further including spring means for biasing said pawl means into engagement with said gear teeth of said continuous counter ring and said intermittent counter ring.

7. The powder inhaler according to claim 6, wherein said pawl means includes a pawl for engagement within the gear teeth of one of said continuous counter ring and said intermittent counter ring, and a pawl extension secured to the end of said spring means and positioned at a height above said pawl for engagement within the gear teeth of the other of said continuous counter ring and said intermittent counter ring.

8. The powder inhaler according to claim 5, wherein said gear teeth of said continuous counter ring are arranged in correspondence with said counting indicia thereon, and said gear teeth of said intermittent counter ring are arranged in correspondence with said counting indicia thereon.

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9. The powder inhaler according to claim 5, wherein the gear teeth of said continuous counter ring include a plurality of successive first gear teeth of a first depth and at least one second gear tooth of a second, greater depth, each said second gear tooth being positioned after every predetermined number of said first gear teeth; and said intermittent counter ring includes a plurality of successive third gear teeth of a depth equal to the depth of each said second gear tooth of said continuous counter ring so that said pawl means engages with successive ones of said first gear teeth during successive dosing operations and engages with one said second gear tooth and a third gear tooth of said intermittent counter ring after a plurality of the dosing operations.

10. The powder inhaler according to claim 9, wherein said first and second gear teeth are formed on an inner surface of said continuous counter ring and said third gear teeth are formed on an inner surface of said intermittent counter ring.

11. The powder inhaler according to claim 5, wherein said pawl means engages said gear teeth of said continuous counter ring and said intermittent counter ring to rotate said continuous counter ring and said intermittent counter ring in a first rotational direction, and further including detent means for preventing rotation of said continuous counter ring and said intermittent counter ring in a second rotational direction opposite to said first rotational direction.

12. The powder inhaler according to claim 11, wherein said detent means includes first rotation prevention detent means mounted on said base for engaging with one of said first and second gear teeth to prevent rotation of said continuous counter ring in

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said second rotational direction and second rotation prevention detent means mounted on said base for engaging with one of said third gear teeth to prevent rotation of said intermittent counter ring in said second rotational direction.

13. The powder inhaler according to claim 5, wherein said actuating means further includes pawl driver means for incrementally rotating said pawl means, said pawl driver means including a retainer rotatably mounted on said base coaxially with said continuous counter ring and said intermittent counter ring, said retainer including first pawl driver means for engaging with one side of said pawl means to incrementally rotate said pawl means in a first rotational direction at the end of rotation of said retainer in said first rotational direction and second pawl driver means for engaging an opposite side of said pawl means to incrementally rotate said pawl means in a second, opposite rotational direction at the end of rotation of said retainer in said second, opposite rotational direction.

14. The powder inhaler according to claim 13, wherein said first and second pawl driver means are formed as opposite edges of an arcuate pawl driving wall connected with said retainer.

15. The powder inhaler according to claim 13, wherein said first and second pawl driver means are formed as radially extending pawl driving end walls connected with said retainer.

16. The powder inhaler according to claim 13, wherein said first and second pawl driver means are spaced apart by a distance such that rotation of said retainer by a first arcuate distance causes incremental

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rotation of said pawl means by a second smaller arcuate distance.

17. The powder inhaler according to claim 13, wherein said powder housing means includes holding means for carrying said retainer with said powder housing means during said relative rotation between said metering plate means and said powder housing means about said common central axis.

18. The powder inhaler according to claim 17, wherein said holding means includes at least one drive slot in one of said powder housing means and said retainer, and at least one drive ear in the other of said powder housing means and said retainer, said at least one drive ear engaging within said at least one drive slot.

19. The powder inhaler according to claim 5, wherein the gear teeth of said intermittent counter ring have a configuration with an outer, substantially circumferentially extending portion and a sloped portion extending inwardly from said circumferentially extending portion.

20. The powder inhaler according to claim 4, wherein said continuous counter ring is rotatably mounted on said base, and said intermittent counter ring is rotatably mounted on said continuous counter ring coaxially with said continuous counter ring.

21. The powder inhaler according to claim 4, wherein said intermittent counter ring is rotatably mounted on said base, and said continuous counter ring is rotatably mounted on said intermittent counter ring coaxially with said intermittent counter ring.

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22. The powder inhaler according to claim 1, further comprising:

nozzle means for breaking up agglomerates of powdered material from said inhalation conduit to form micronized powdered material and for mixing said micronized powdered material with suction air, said nozzle means including either:

(a) cavity means for changing the direction of flow of said powder from said first direction of said inhalation conduit to a second direction different from said first direction, and swirl means for substantially continuously changing the direction of flow of said powder in said second direction in said cavity means; or

(b) an outer wall defining a conduit having a shape substantially of an inverted tornado.

23. The powder inhaler according to claim 22, further including lock-out means for preventing said relative rotation of said powder housing means and said metering plate means after a predetermined number of doses have been dispensed.

24. The powder inhaler according to claim 23, further including a base on which said metering plate means is non-rotatably mounted and an adapter non-rotatably mounted on said base, said lock-out means including a dosage limiter tab on said adapter, and tab means on said counter means for engaging with said dosage limiter tab when said predetermined number of doses have been dispensed.

25. The powder inhaler according to claim 1, further comprising closure cap means for covering said powder housing means and for priming said powder inhaler for use, said closure cap means including priming means for rotating said powder housing means such that said

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inhalation conduit is in communication with said metered dose hole means when said closure cap means is removed from covering relation of said powder housing means and for rotating said powder housing means such that said inhalation conduit is out of communication with said metered dose hole means and such that said powder supply opening comes into communication with said metered dose hole means when said closure cap means is secured in covering relation to said powder housing means.

26. The powder inhaler according to claim 25, further including adapter means rotatably mounted with respect to said powder housing means and non-rotatably mounted with respect to said metering plate means, said adapter means including first helical threads and said closure cap means including second helical threads for engaging with said first helical threads to threadedly connect said closure cap means on said adapter means.

27. The powder inhaler according to claim 26, wherein said powder housing means includes at least one driving recess and said priming means includes rib means on an inside surface of said closure cap means for engaging with said at least one driving recess to rotate said powder housing means such that said inhalation conduit is in communication with said metered dose hole means when said closure cap means is threadedly removed from said covering relation of said powder housing means and for rotating said powder housing means such that said inhalation conduit is out of communication with said metered dose hole means and such that said powder supply opening comes into communication with said metered dose hole means when said closure cap means is threadedly secured to said adapter means in covering relation to said powder housing means.

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28. A counter for a powder inhaler wherein doses of powdered material are metered and dispensed by means of reciprocating rotational motion, comprising:

a continuous counter ring having counting indicia thereon;

an intermittent counter ring adjacent to said continuous counter ring, said intermittent counter ring having counting indicia thereon;

display means through which one of said counting indicia from said continuous counter ring and one of said counting indicia from said intermittent counter ring are displayed to indicate a count corresponding to a number of doses of powdered material that have been dispensed or remain to be dispensed; and

actuating means for rotating said continuous counter ring one increment each time that a dose of the powdered material is dispensed to display another one of said counting indicia of said continuous counter ring, and for rotating said intermittent counter ring one increment for a predetermined number of rotational increments of said continuous counter ring to display another one of said counting indicia of said intermittent counter ring.

29. The counter according to claim 28, wherein said powder inhaler includes a base, and said continuous counter ring and said intermittent counter ring are rotatably mounted relative to said base.

30. The counter according to claim 29, wherein said continuous counter ring has gear teeth therearound, said intermittent counter ring has gear teeth therearound, and said actuating means further includes pawl means, engaging with said gear teeth of said continuous counter ring and said intermittent counter ring, for rotating said continuous counter ring one increment each time that a dose of the powdered material is dispensed to display another one of said counting indicia of said continuous counter ring

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through said display means, and for rotating said intermittent counter ring one increment every predetermined number of rotational increments of said continuous counter ring to display another one of said counting indicia of said intermittent counter ring through said display means.

31. The counter according to claim 30, further including spring means for biasing said pawl means into engagement with said gear teeth of said continuous counter ring and said intermittent counter ring.

32. The counter according to claim 31, wherein said pawl means includes a pawl secured to the end of said spring means for engagement within the gear teeth of one of said continuous counter ring and said intermittent counter ring, and a pawl extension secured to the end of said spring means and positioned at a height above said pawl for engagement within the gear teeth of the other of said continuous counter ring and said intermittent counter ring.

33. The counter according to claim 30, wherein said gear teeth of said continuous counter ring are arranged in correspondence with said counting indicia thereon, and said gear teeth of said intermittent counter ring are arranged in correspondence with said counting indicia thereon.

34. The counter according to claim 30, wherein the gear teeth of said continuous counter ring include a plurality of successive first gear teeth of a first depth and at least one second gear tooth of a second, greater depth, each said second gear tooth being positioned after every predetermined number of said first gear teeth; and said intermittent counter ring includes a plurality of successive third gear teeth of

a depth equal to the depth of each said second gear tooth of said continuous counter ring so that said pawl means engages with successive ones of said first gear teeth during successive dosing operations and engages with one said second gear tooth of said continuous counter ring and one said third gear tooth of said intermittent counter ring after a plurality of the dosing operations.

35. A counter according to claim 34, wherein said first and second gear teeth are formed on an inner surface of said continuous counter ring and said third gear teeth are formed on an inner surface of said intermittent counter ring.

36. the counter according to claim 30, wherein said pawl means engages said gear teeth of said continuous counter ring and said intermittent counter ring to rotate said continuous counter ring and said intermittent counter ring in a first rotational direction, and further including detent means for preventing rotation of said continuous counter ring and said intermittent counter ring in a second rotational direction opposite to said first rotational direction.

37. The counter according to claim 36, wherein said detent means includes first rotation prevention detent means mounted on said base for engaging with one of said first and second gear teeth to prevent rotation of said continuous counter ring in said second rotational direction and second rotation prevention detent means mounted on said base for engaging with one of said third gear teeth to prevent rotation of said intermittent counter ring in said second rotational direction.

38. The counter according to claim 30, further including pawl driver means for incrementally rotating said pawl means, said pawl driver means including a retainer rotatably mounted on said base coaxially with said continuous counter ring and said intermittent counter ring, said retainer including first pawl driver means for engaging with one side of said pawl means to incrementally rotate said pawl means in a first rotational direction at the end of rotation of said retainer in said first rotational direction to cause said pawl means to engage a successive gear tooth of said continuous counter ring, and second pawl driver means for engaging an opposite side of said pawl means to incrementally rotate said pawl means in a second, opposite rotational direction at the end of rotation of said retainer in said second, opposite rotational direction to cause said pawl means to incrementally rotate said continuous counter ring therewith.

39. The counter according to claim 38, wherein said first and second pawl driver means are formed as opposite edges of an arcuate pawl driving wall connected with said retainer.

40. The counter according to claim 38, wherein said first and second pawl driver means are formed as radially extending pawl driving end walls connected with said retainer.

41. The counter according to claim 38, wherein said first and second pawl driver means are spaced apart by a distance such that rotation of said retainer by a first arcuate distance causes incremental rotation of said pawl means by a second smaller arcuate distance.

42. The counter according to claim 30, wherein the gear teeth of said intermittent counter ring have a

configuration with an outer, substantially circumferentially extending portion and a sloped portion extending inwardly from said circumferentially extending portion.

43. The counter according to claim 29, wherein said continuous counter ring is rotatably mounted on said base, and said intermittent counter ring is rotatably mounted on said continuous counter ring coaxially with said continuous counter ring.

44. The counter according to claim 29, wherein said intermittent counter ring is rotatably mounted on said base, and said continuous counter ring is rotatably mounted on said intermittent counter ring coaxially with said intermittent counter ring.

45. A nozzle for reducing particle size of agglomerates of powdered material entering the nozzle from an inhalation conduit extending in a first direction in a powder inhaler, to form micronized powdered material and for mixing said micronized powdered material with suction air, said nozzle comprising either:

(a) cavity means for changing the direction of flow of said powder from said first direction of said inhalation conduit to a second direction substantially perpendicular to said first direction, and swirl means for substantially continuously changing the direction of flow of said powder in said second direction in said cavity means; or

(b) an outer wall defining a conduit having a shape substantially of an inverted tornado defined by a continuously changing cross-sectional circular area having a radius which changes exponentially by depth from a lower outer circle of a first radius to an upper circle of a second, smaller radius, and having an origin which moves in a circle that changes with depth.

46. The nozzle according to claim 45 having the cavity means, wherein said cavity means is defined by a top wall and a skirt connected to a periphery of said top wall in surrounding relation to said swirl means.

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47. The nozzle according to claim 46, wherein said top wall includes an opening for changing the direction of flow of said powder from said second direction of said cavity means substantially back to said first direction.

48. The nozzle according to claim 47, wherein said top wall has a circular shape and said opening is centrally located in said top wall.

49. The nozzle according to claim 47, wherein said swirl means includes a curved wall extending from said opening to said skirt.

50. The nozzle according to claim 49, wherein said curved wall extends in a substantially spiral manner.

51. The nozzle according to claim 50, wherein said curved wall has a first curved wall section extending partially about said central opening and a second curved wall section extending from one end of said first curved wall section to said skirt, each of said first and second curved wall sections extending essentially along a circular arc, with the radius of the circular arc of said second curved wall section being greater than the radius of the circular arc of said first curved wall section.

52. The nozzle according to claim 51, wherein said curved wall is connected with said top wall.

53. The nozzle according to claim 51, further including chimney means extending from said top wall in surrounding relation to said central opening for changing the direction of flow of said powder from said second direction of said cavity means substantially back to said first direction.

54. The nozzle according to claim 53, wherein said chimney means has a central axis and said inhalation conduit has a central axis parallel to and offset from the central axis of said chimney means.

55. The nozzle according to claim 45 and having the inverted tornado shape, wherein said shape is defined by the equation:

$$(x-a)^2 + (y-b)^2 = c_0 + c_1 * e^{kz},$$

where $a = a_0 + \sin(a_1 + \pi)$,

$b = b_0 + \cos(b_1 + \pi)$,

$c_0 + c_1$ is the radius of a lowest cross-sectional circular area of the inverted tornado shape,

c_0 is the radius of an uppermost cross-sectional circular area of the inverted tornado shape,

$a_0 + a_1$ is the x-coordinate of the lowest cross-sectional circular area,

a_0 is the x-coordinate of the uppermost cross-sectional circular area,

$b_0 + b_1$ is the y-coordinate of the lowest cross-sectional circular area,

b_0 is the y-coordinate of the uppermost cross-sectional circular area,

x , y and z are x-, y- and z- coordinates, and

k is an exponential coefficient which defines the geometry of a spiral of the inverted tornado shape.

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